

Lithium 7: *a phenomenologist's perspective*

<http://arxiv.org/abs/arXiv:1206.2396>

Fabio Iocco
Instituto de Física Teórica UAM/CSIC
Madrid

fabio.iocco.astro .AT. gmail.com

ICTP-SAIFR, Cosmology workshop
Sao Paulo, February 20th 2014

Lithium 7:

*an amazing observable for precision cosmology**

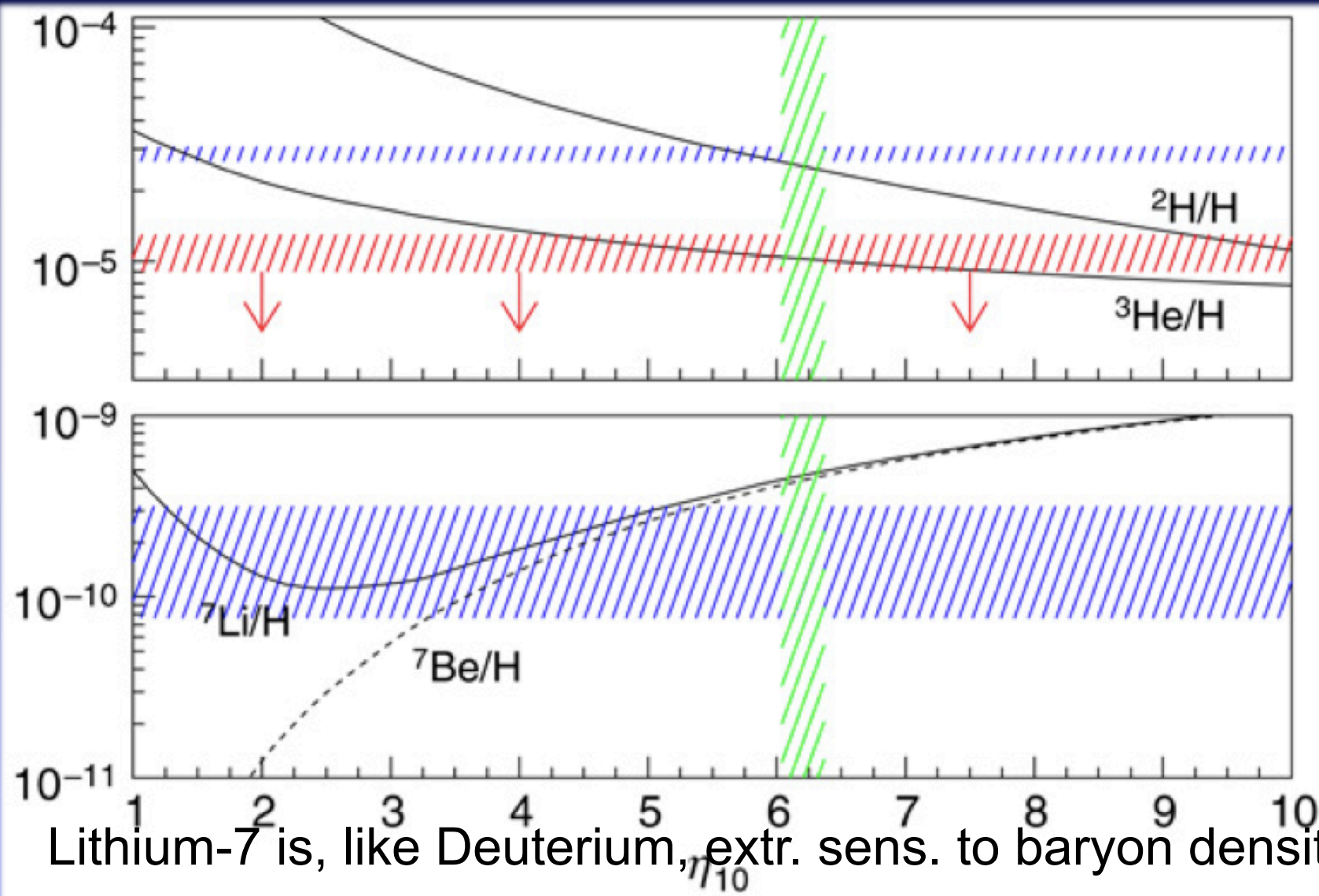
Fabio Iocco

*Instituto de Física Teórica UAM/CSIC
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* please read until the last slide

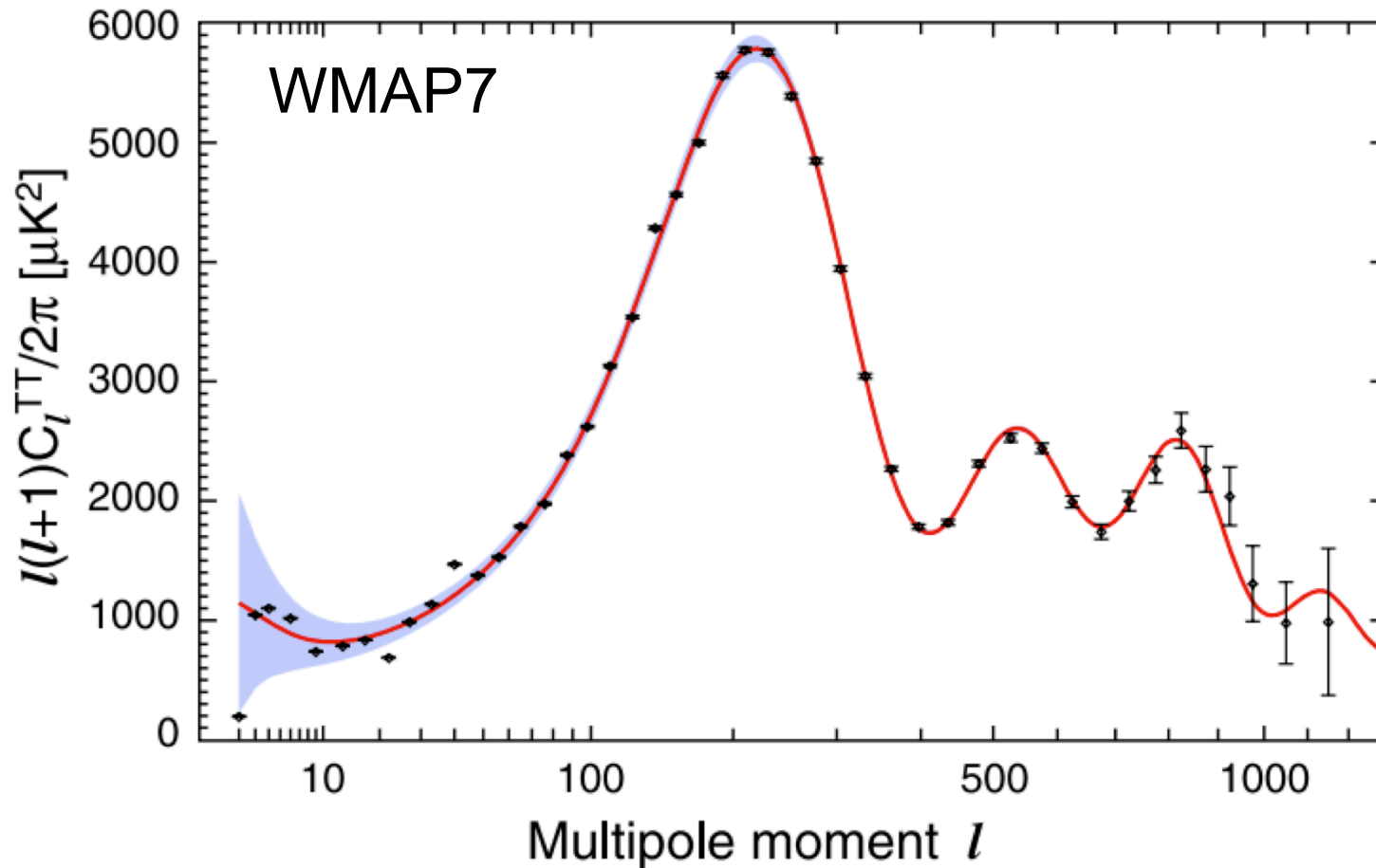
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Rationale



Lithium-7 is, like Deuterium, extr. sens. to baryon density

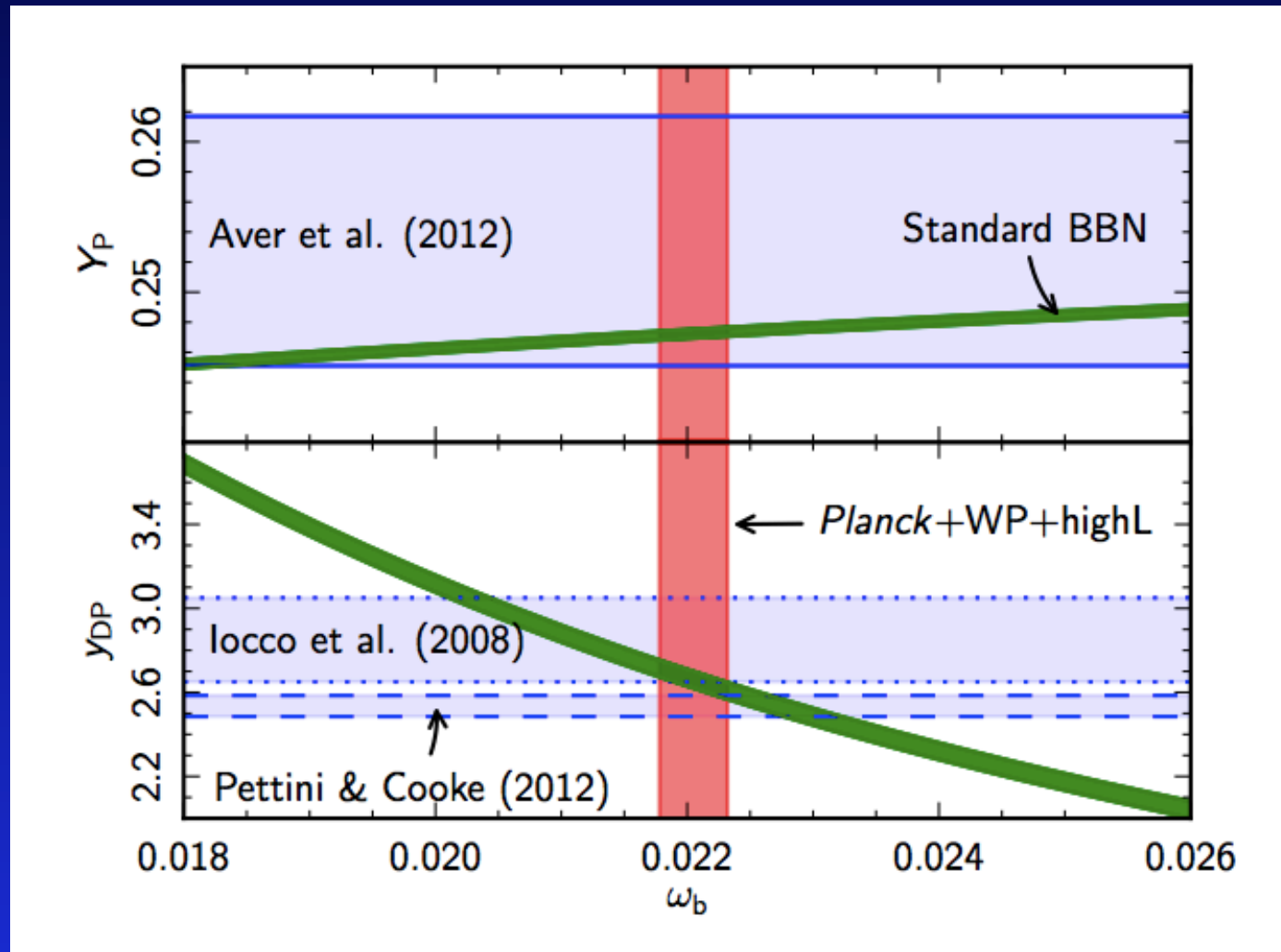
However (or even better)
CMB determination of ω_b



$\omega_b = 0.02258 \pm 0.00058$
independent determination

PLANCK and BBN Cosmology

Baryon density ω_b

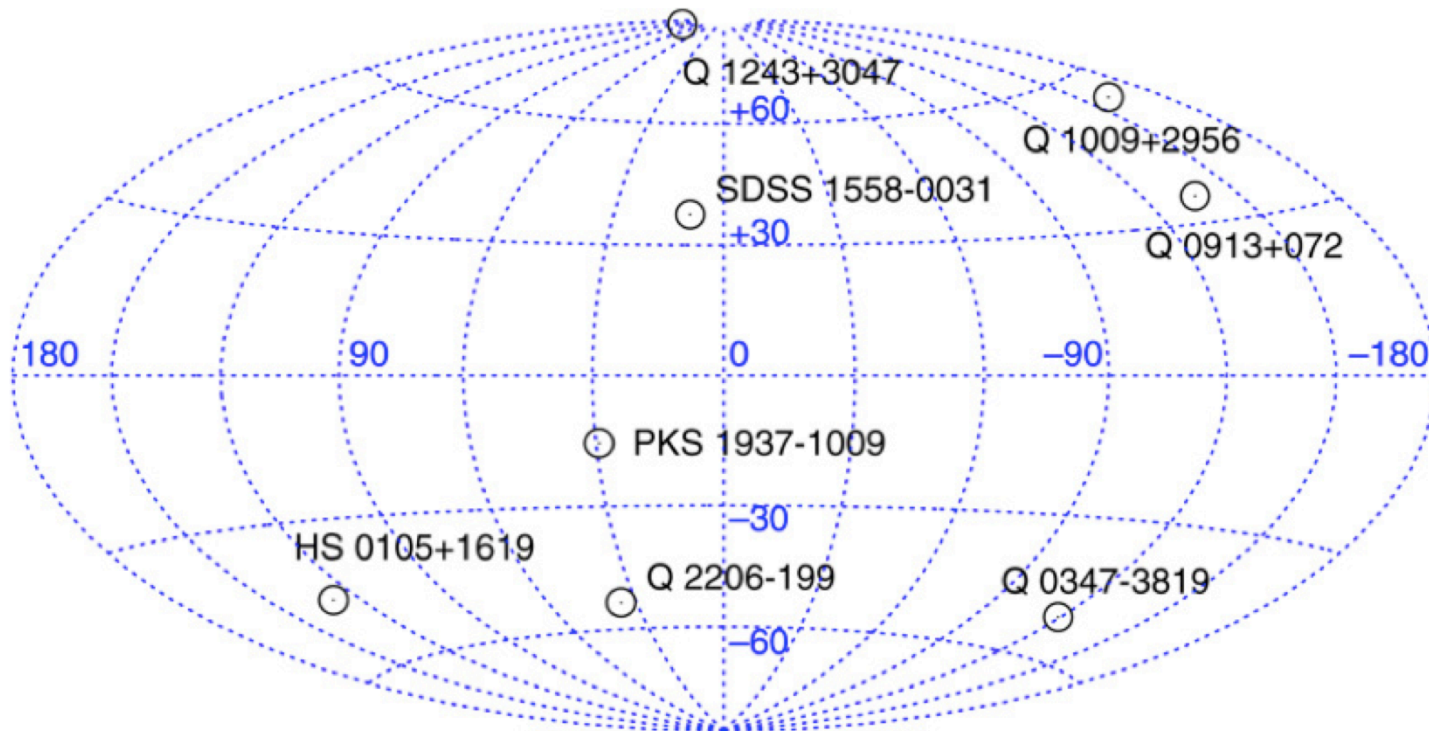


$$z_{\text{BBN}} \approx 10^7 - 10^5$$
$$z_{\text{CMB}} \approx 10^3$$

Agreement!!

Deuterium observations: fun facts

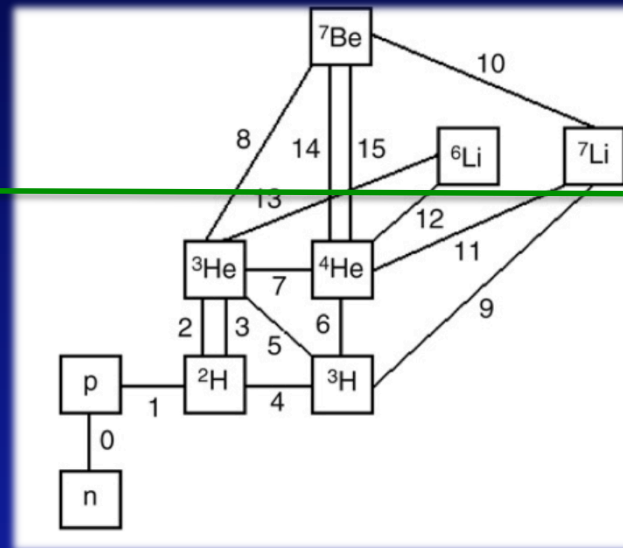
F. Iocco et al. / Physics Reports 472 (2009) 1–76



Easy to destroy, absorbers placed at $2.0 < z < 3.5$
(semi-)convincing arguments for being observing primordial Deuterium

Primordial Nucleosynthesis (BBN):

Cosmology +
Baryonic physics



Light primordial
element abundances

Network well known,
biggest uncertainties (in standard formulation)
from nuclear reaction rates

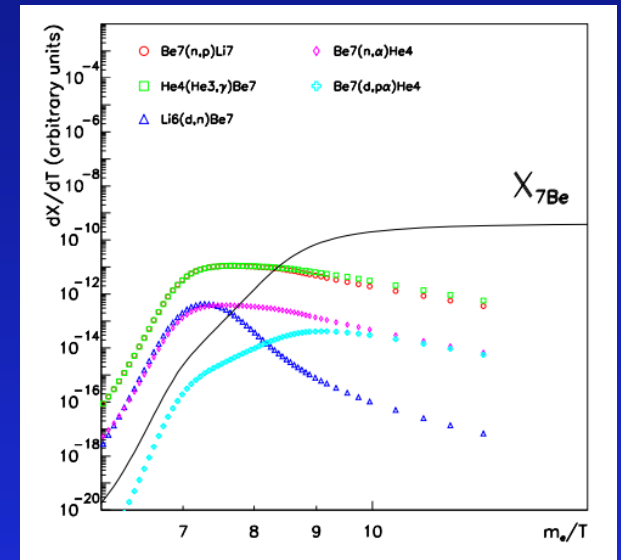
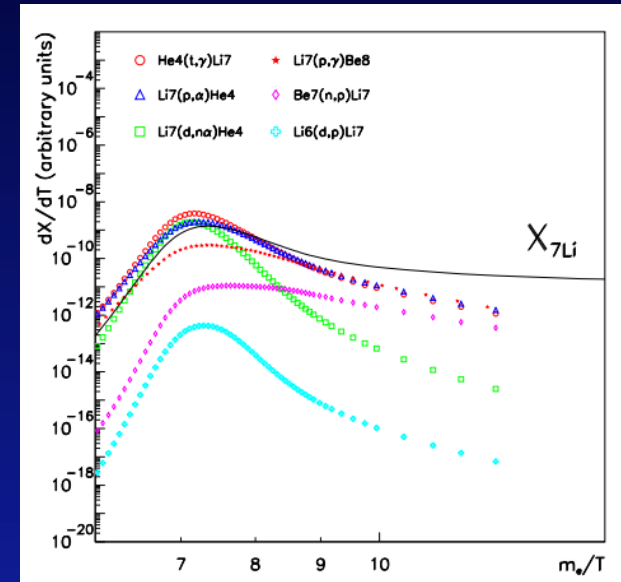
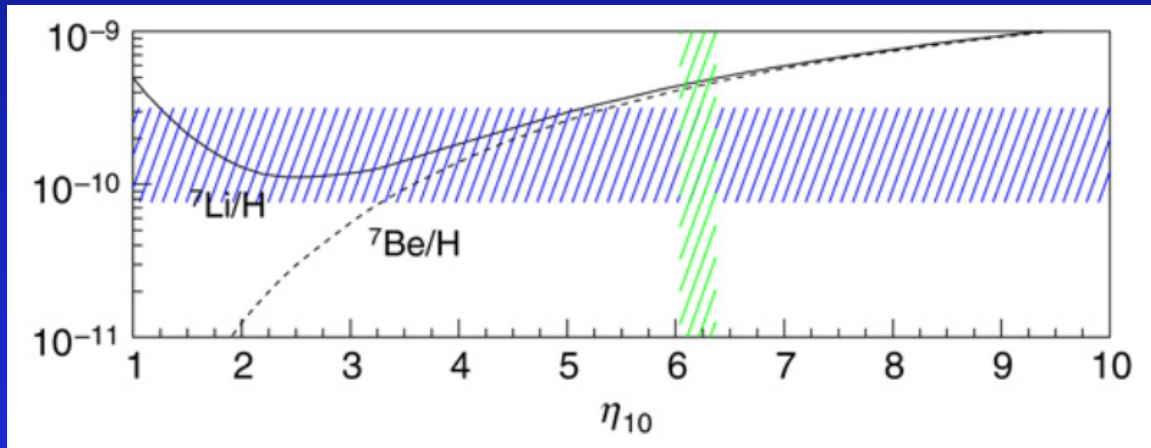
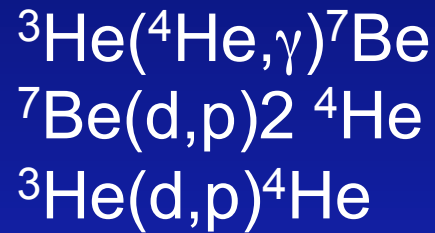
BBN Lithium

BBN prediction:

$$X_{\{^7\text{Li}\}} = 4.7 \pm 0.3 \pm 0.4 \times 10^{-10} \quad (\approx 0.1 \text{ dex})$$



Most relevant reactions:



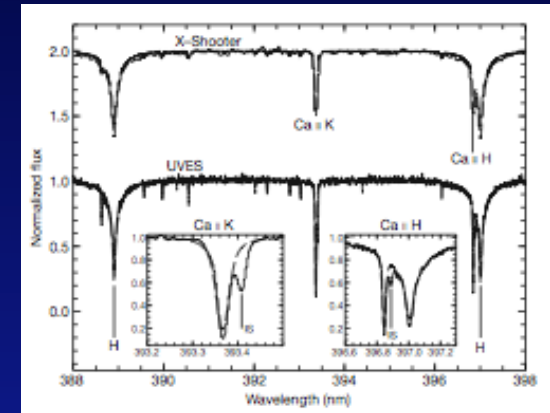
Observing Lithium in the halo: today

Great resolution, photometry
and spectroscopy, high objects #,
Detailed atmosphere models.

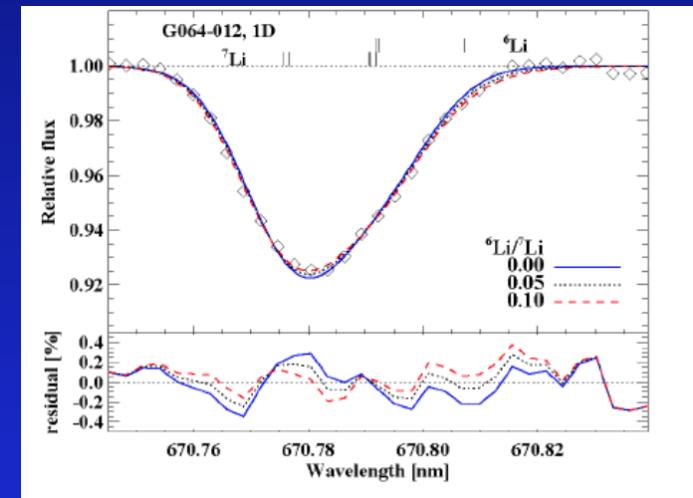
Still, small issue with atmospheres

LTE or Non LTE, 3D...

Today's technology still allows for
100K uncertainty, \rightarrow 0.2 dex in Li abundance
(not much, see later)



[Caffau et al. '11]



[Asplund & Melendez '08]

Keck + HIRES

Where do we observe Lithium?

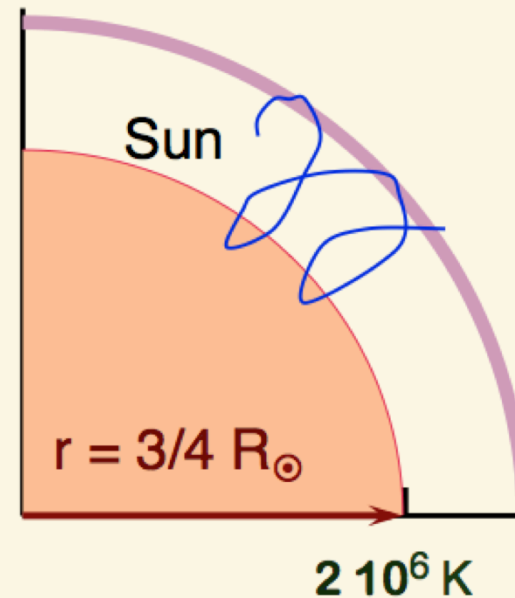
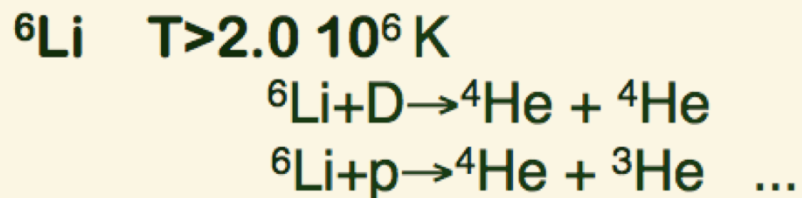
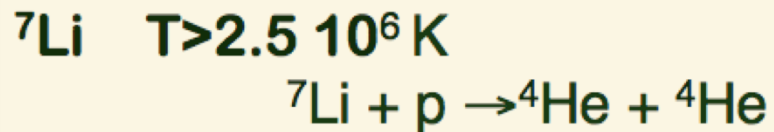
Atmospheres of metal-poor stars
in our Galaxy's halo

But...
Lithium is a very fragile element

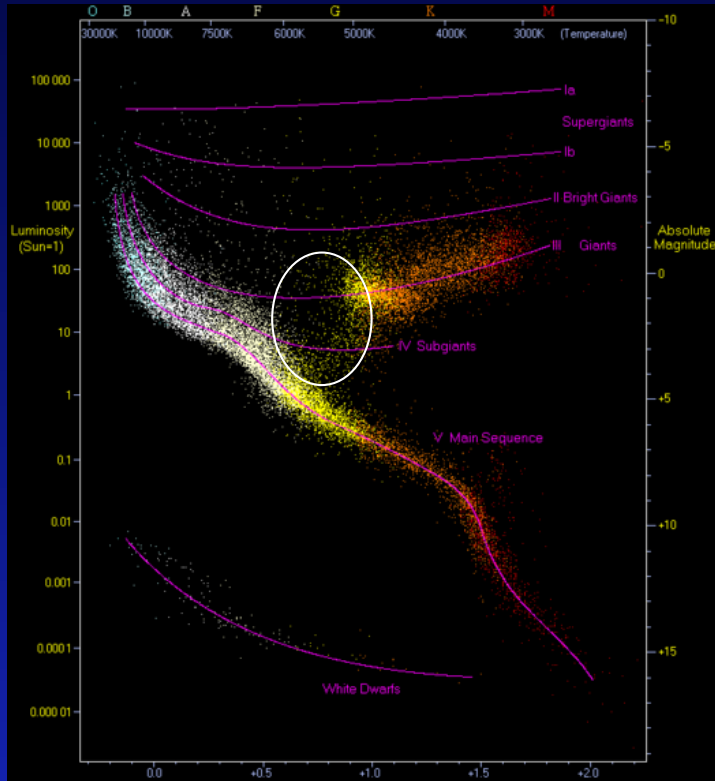
if mixing between the atmosphere and these hot layers

⇒ lithium is destroyed little by little in the atmosphere

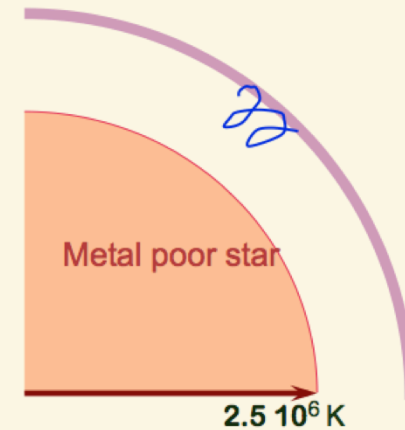
destroyed :



Some “special” stars: Turn-off, metal-poor, halo population



In warm **metal-poor** stars
(turnoff stars: $T_{\text{eff}} > 5900\text{K}$)
mixing is not as deep as in solar
type stars and
lithium is preserved.



A priori :

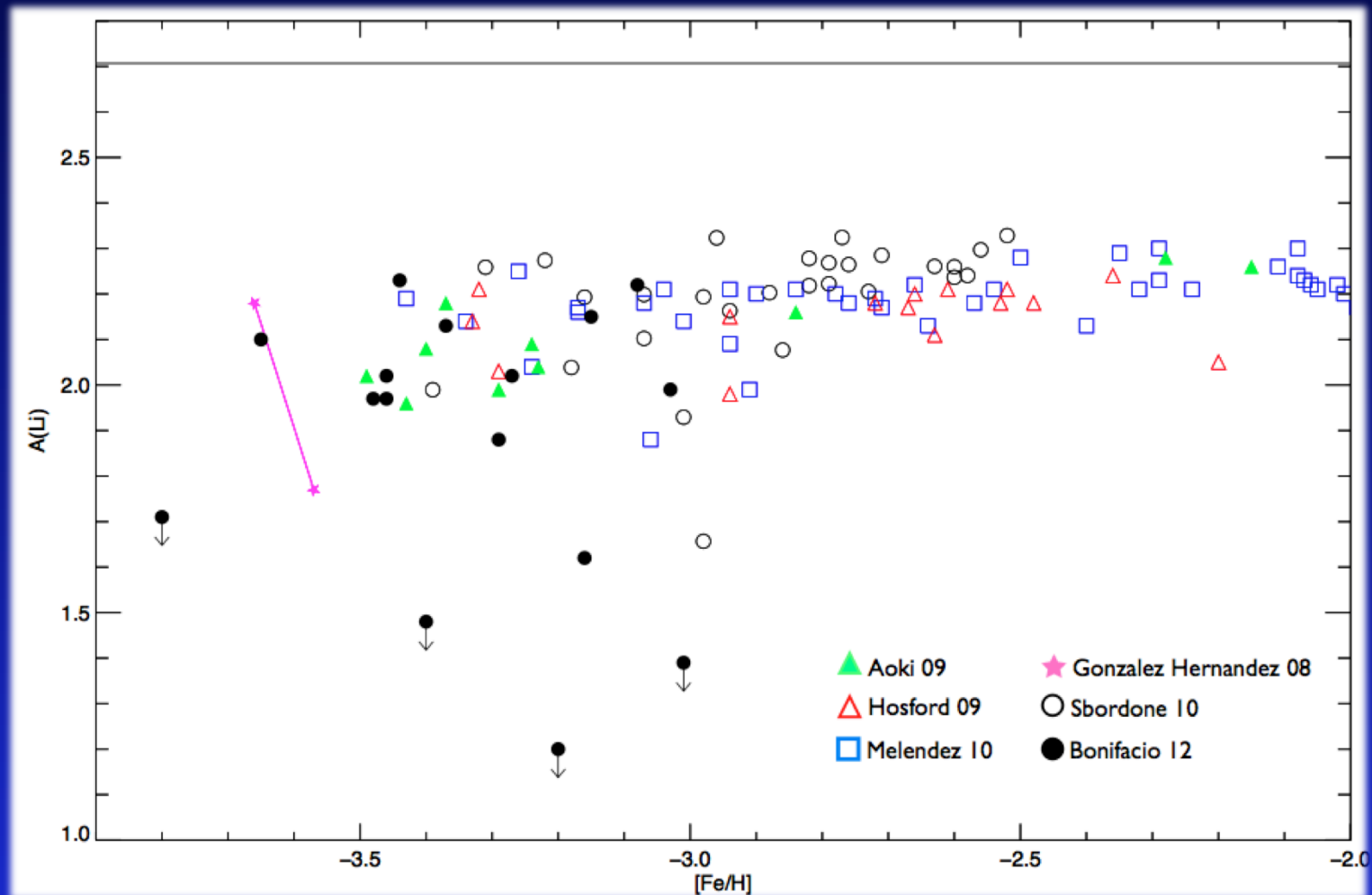
Abundance of lithium in old metal-poor turnoff stars =
Abundance of lithium in the primitive galactic matter

[courtesy of M. Spite]

A priori: the lithium abundance in T-off stars is the same as
its beginning. A priori... means what?

The ${}^7\text{Li}$ observations* (in the MW halo)

annus domini 2012

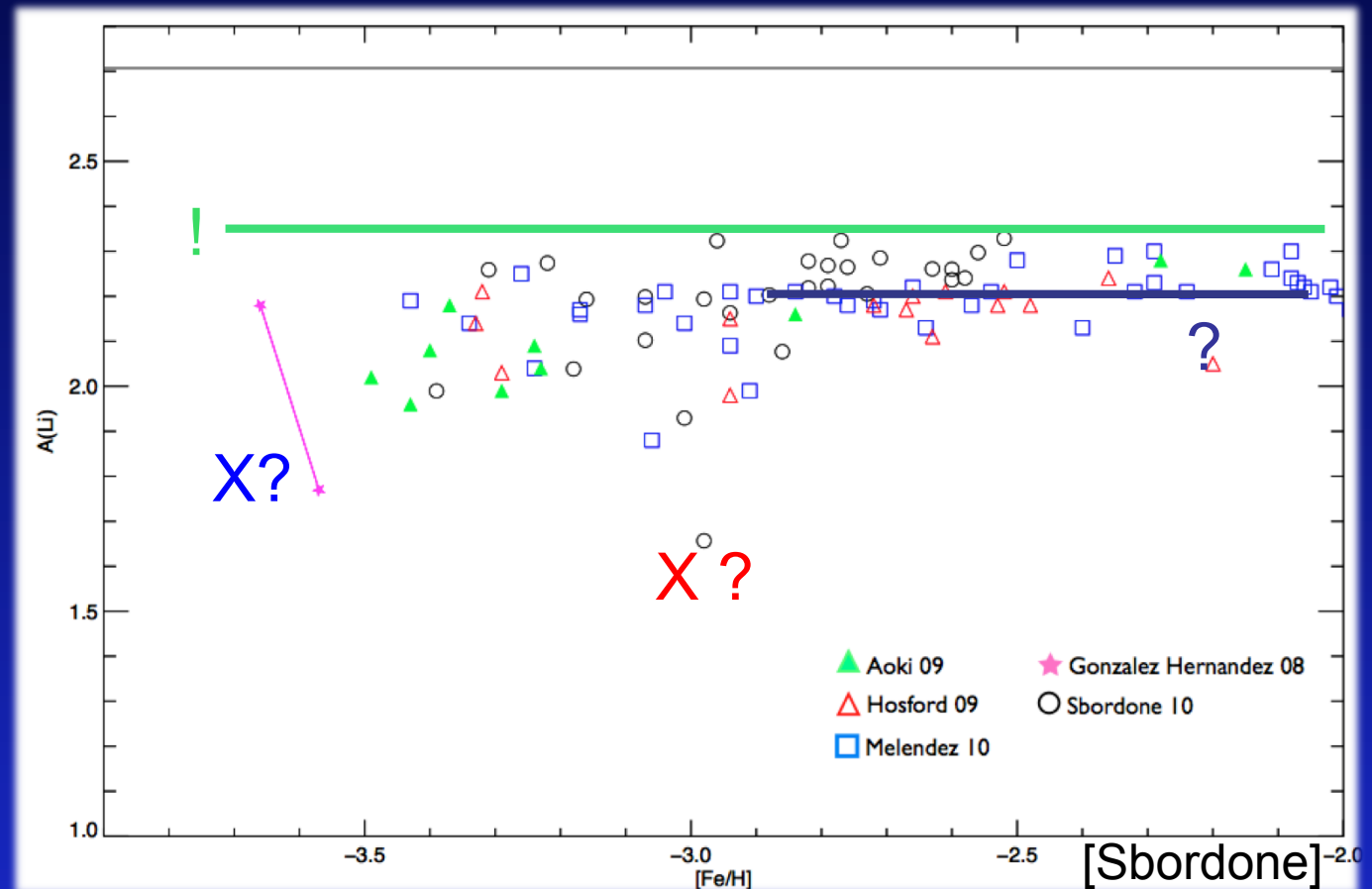


*of the atmospheric abundance of:
turn-off, metal-poor, halo stars

[Courtesy of L. Sbordone]

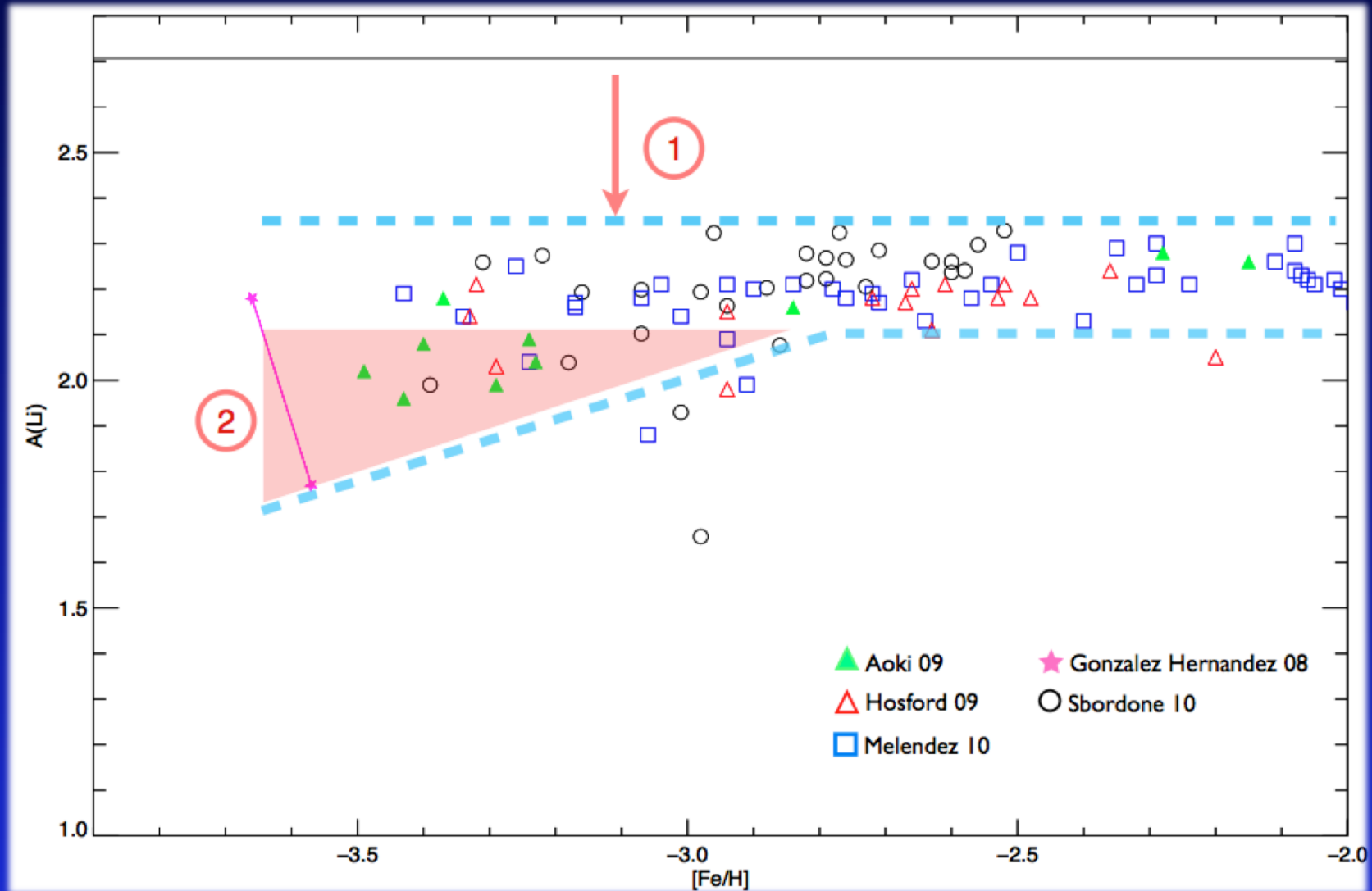
Observations, let's play a game: (if you want to do cosmology with a value, find a value)

Can anybody
identify a special
value in this plot?



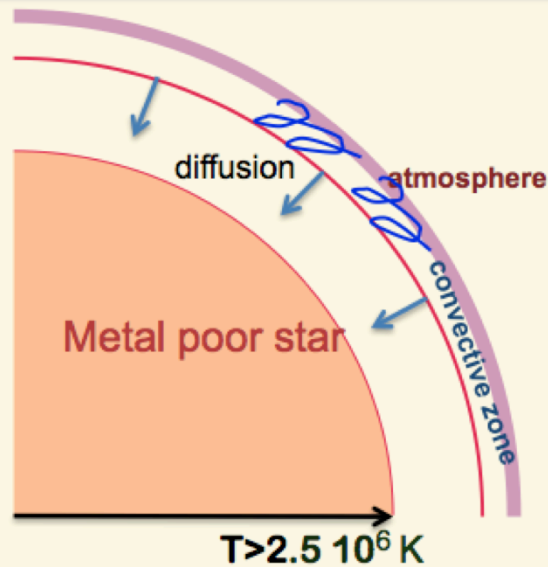
Plateau in this case is the “roof” plateau,
an upper limit, an “envelope”

State of art of halo stars, a.d. 2012 (the Lithium “problem”?)



[Courtesy of L. Sbordone]

“A priori”, Lithium is the same at Turn-off than at ZAMS. BUT



Atomic diffusion ?

Atomic diffusion is a slow gravitational settling of the elements below the convective zone.

It "is always present in stars. It cannot be turned off. It can only be rendered inefficient by sufficient mass motion either due to meridional circulation or turbulence." (Michaud et al., 1984)

If diffusion is efficient, the lithium abundance in the convection zone of a metal-poor dwarf decreases with time because of the settling of Li.

Characteristic time scale:

$$1/\tau_{\text{Li}} = 2.3 \cdot 10^{-22} A T^{3/2} M / Z^2 M_Z$$

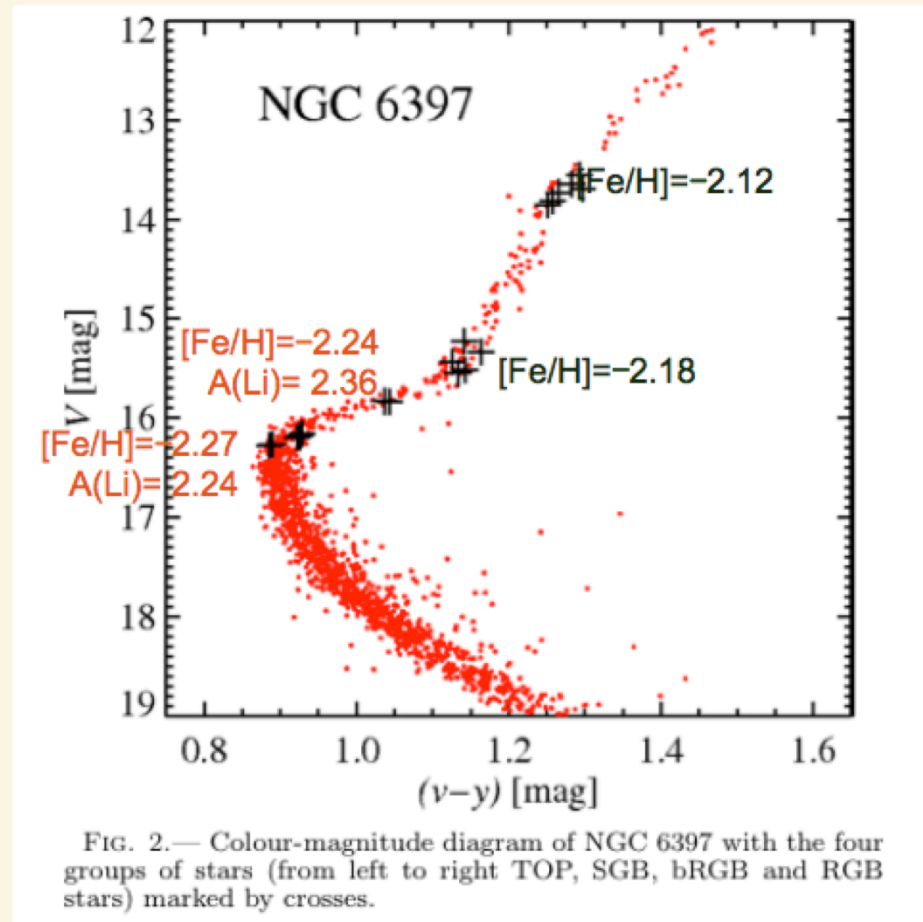
A atomic mass of Li **M** mass of the star **T** temperature
Z atomic number of Li **M_Z** mass of the mixed zone

“A priori”, Lithium is the same at Turn-off than at ZAMS. BUT

NGC 6397

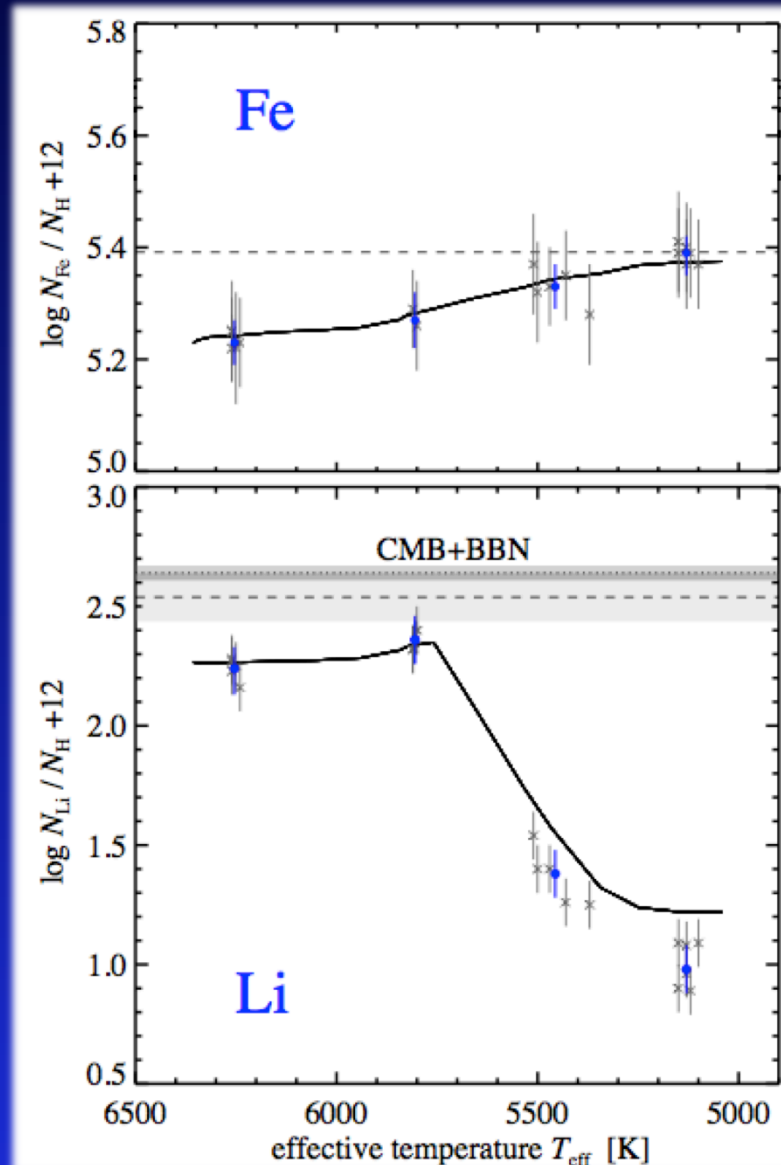
Korn et al. 2006, 2007 found an evolution of $[Fe/H]$ along the HR diagram. Turnoff stars have a lower iron abundance than giants.

⇒ interpreted in terms of turbulent diffusion this would induce that the lithium abundance in turnoff stars would have been depleted by **0.26 dex** compared to the original value...



original lithium abundance
 $2.24 + 0.26 = 2.50$???

Globular cluster studies



Looking for Lithium abundance correlation with stellar evolution

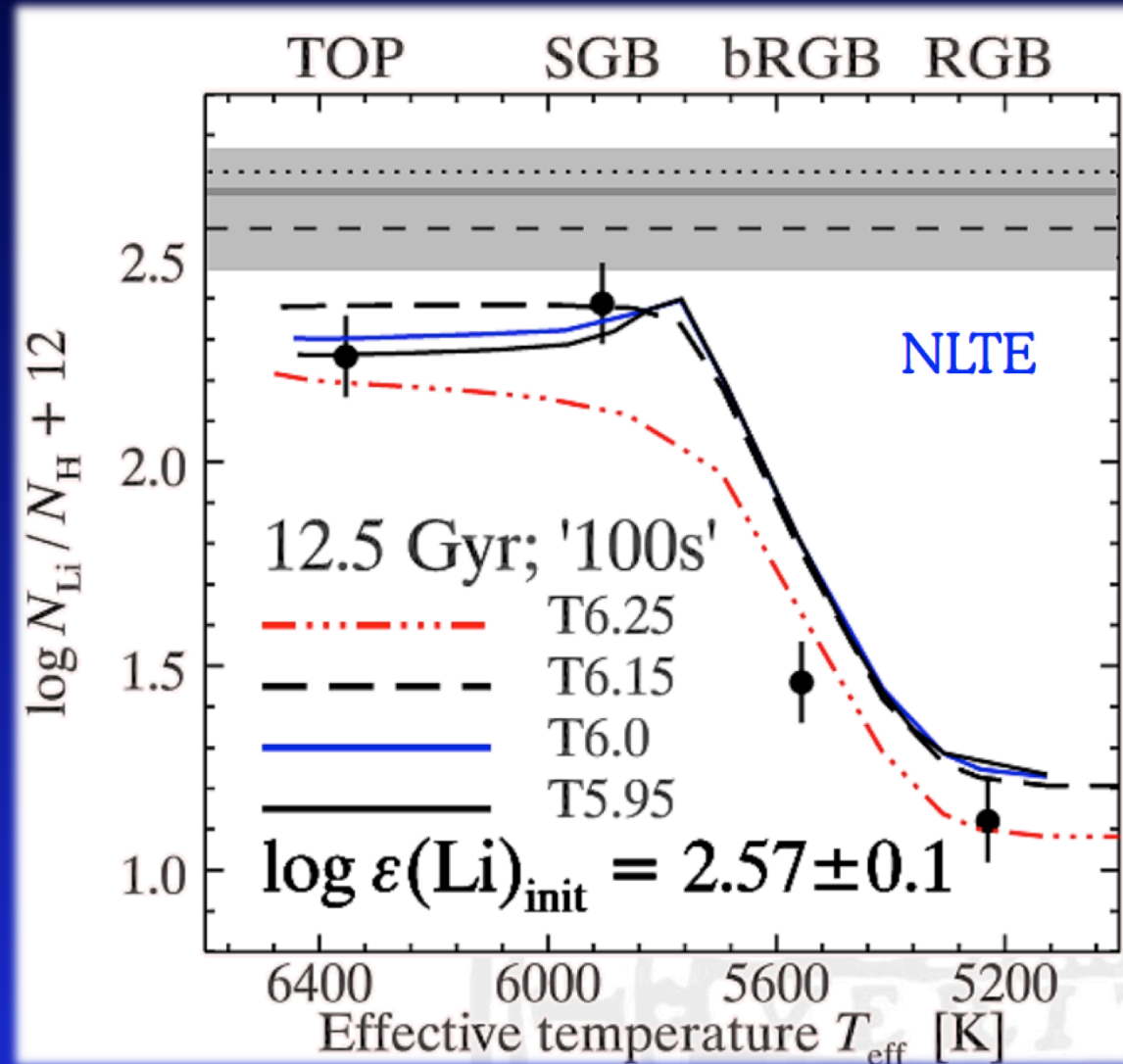
Including:
microturbulence
atomic diffusion

[...] diffusion is predominantly responsible for the low apparent stellar lithium abundance [...]

Globular cluster studies

Looking for Lithium abundance correlation with stellar evolution

Including:
microturbulence
atomic diffusion



[Fe/H] = [-2.28,-2.12]

[...] diffusion is predominantly responsible for the low apparent stellar lithium abundance [...]

[Korn et al 2006-07]
[Nordlander et al, '12]

Globular cluster studies

Show, that starting with a ZAMS abundance of lithium-7 equal to BBN one, evolving stars including diffusion and (parametric models of) microturbulence, It is possible to obtain lithium-7 abundances compatible with those observed in the atmosphere of turn-off, metal poor stars.

[...] diffusion is predominantly responsible for the low apparent stellar lithium abundance [...]

[Korn et al 2006-07]

[Nordlander et al, '12]

Does the lithium-7 observed in the atmospheres of such stars reflects the Primordial abundance? (i.e., is it possible to do cosmology with it?)

In situ production/destruction

Try and reconstruct the initial composition of the Earth's atmosphere next to a car with a running carburettor



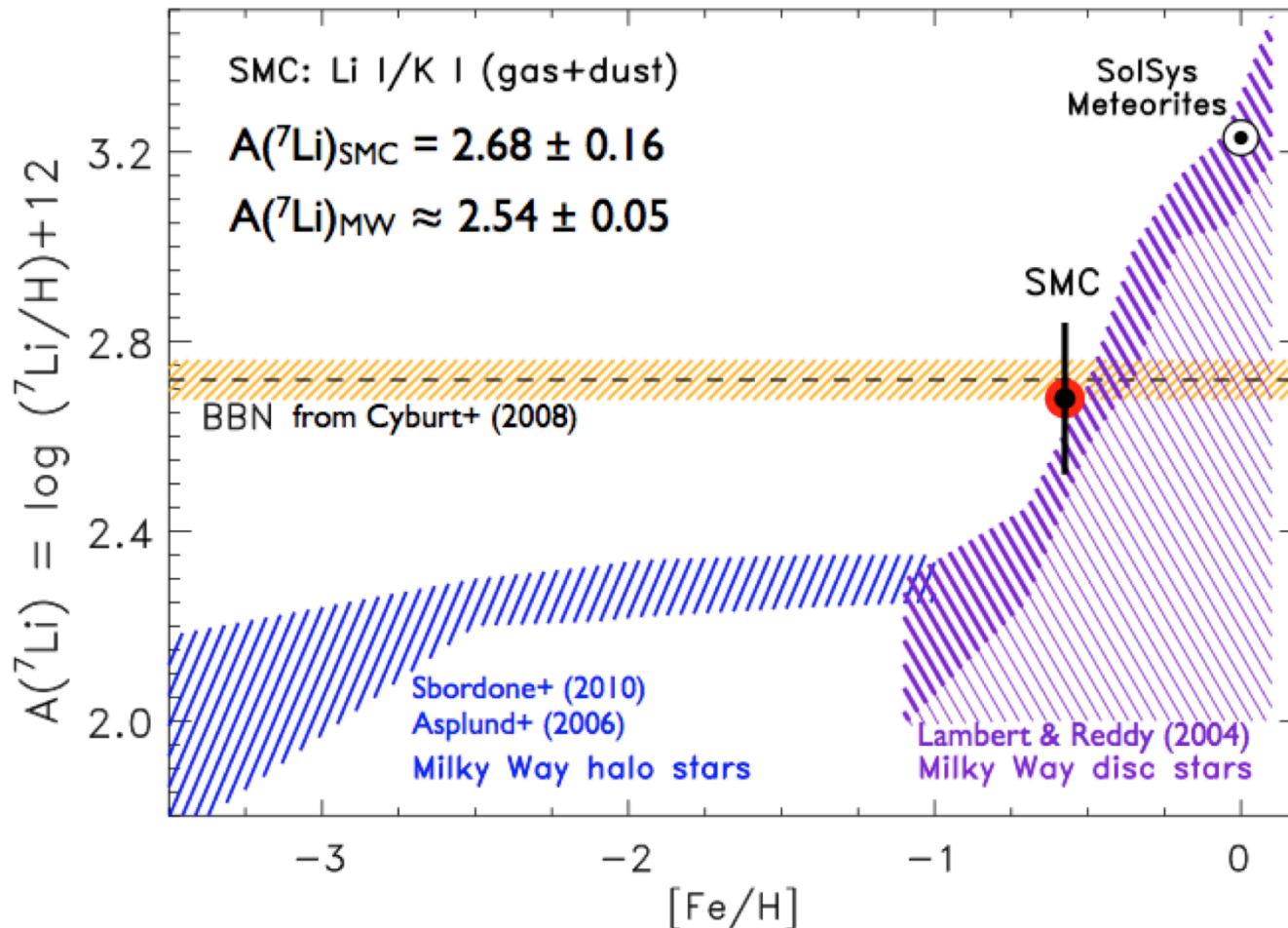
It is a beautiful thing, and can give you a lot of emotions and surprises.
But is it representative of the average environment?

[P. Serpico, talking about ...]

Observations in the “atmosphere”



The Small Magellanic Cloud as probe of pre-galactic Li



Alright: one case

We want more!

Observations of intergalactic lithium-7 are most welcome!

But low absolute abundance
(6 o.o.m. < Deuterium),
also need chemical models to extrapolate to $z=0$

We want more!

Facts

(about lithium-7 abundance in the atmosphere of TO, metal-poor, halo stars)

- Li-7 abundance can't get $A(\text{Li}) > 2.4$ at $[\text{Fe}/\text{H}] = [-3.0, -1.5]$ (some cases, stat. irrelevant)
- Li-7 abundance falls below this value, high dispersion at $[\text{Fe}/\text{H}] < -3.0$

Questions

- Is “this” value of Li-7 “unique”?
- IF unique is there a single explanation?
 - “Which” Lithium Problem?

Concluding (?)

“You have a problem, and the problem is that your problem is not the problem you think you have.”

[My therapist]

- “It looks like grandma’s mood is so much better today!”
- “ Of course son: Lithium never fails. ”

[My dad]

Conclusion and Questions

- Li7 is observed in Turn-off stars of halo and Globular Cluster
 - Trend in metallicity of host star
 - Not a clear “plateau” anymore, but a “roof”/”envelope”
 - Indication of primordial value?
- Indication of an astrophysical mechanism?

Lithium 7:

is it a good observable for precision cosmology?

(Are we sure the lithium-7 we observe is the primordial one?)

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